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BACKSCATTER FROM ICE GROWING ON SHALLOW TUNDRA LAKES
NEAR BARROW, ALASKA, WINTER 1991-92

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INTRODUCTION

The timing of freeze-up and break-up of Arctic lake ice is a potentially useful environmental indicator that could be monitored using SAR. In order to do this, it is important to understand how the properties and structure of the ice during its growth and decay affect radar backscatter and thus lake ice SAR signatures. This problem was previously investigated using uncalibrated photographic products from airborne SLAR instruments (e.g., Weeks et al., 1978, 1981; Mellor, 1982). The availability of radiometrically and geometrically calibrated digital SAR data time series from the Alaska SAR Facility has made it possible for the first time to quantify lake ice backscatter intensity (σ^0) variations. This has been done for ice growing on shallow tundra lakes near Barrow, NW Alaska, from initial growth in September 1991 until thawing and decay in June 1992. Field and laboratory observations and measurements of the lake ice were made in late April 1992.

RESULTS

The field investigations of the coastal lakes near Barrow confirmed previous findings (Weeks et al., 1978, 1981; Mellor, 1982) that, 1) ice frozen to the lake bottom had a dark signature in SAR images, indicating weak backscatter, while, 2) ice that was floating had a bright signature, indicating strong backscatter. At all sites, regardless of whether the ice was grounded or floating, there was a layer of clear, inclusion-free ice overlying a layer of ice with dense concentrations of vertically oriented tubular bubbles. At some sites, there was a third layer of porous, snow-ice overlying the clear ice.

Backscatter intensity values were derived from ERS-1 SAR images for a set of lakes located near the coast at Barrow (Barrow lakes) and for a set of lakes located about 80km inland south of Barrow ('B' lakes). Backscatter intensity profiles for each set of lakes are shown in Figure 1.

When ice growth began in late September, backscatter was low (-12 to -25dB). As the ice grew thicker during the autumn, backscatter rose steadily. Between mid-October and late February, backscatter intensity declined at different times at different lakes, but in each case remained fairly constant thereafter at -15dB to -17dB until mid- to late April. At other lakes, backscatter intensity continued to increase to a maximum of -3 to -8dB in late January and remained fairly constant thereafter at those values until mid- to late April. These patterns are common to both the coastal and inland lakes.

The backscatter records of the coastal and inland lakes differ from April to June (Figure 1). At the coastal lakes, backscatter increases to -8dB to -10dB from those lakes which previously had low backscatter. Conversely, backscatter declines to -17dB to -19dB from those lakes where backscatter was previously high. In contrast, at the inland location, backscatter from all the lakes declines to -17dB to -21dB, regardless of the earlier backscatter record.

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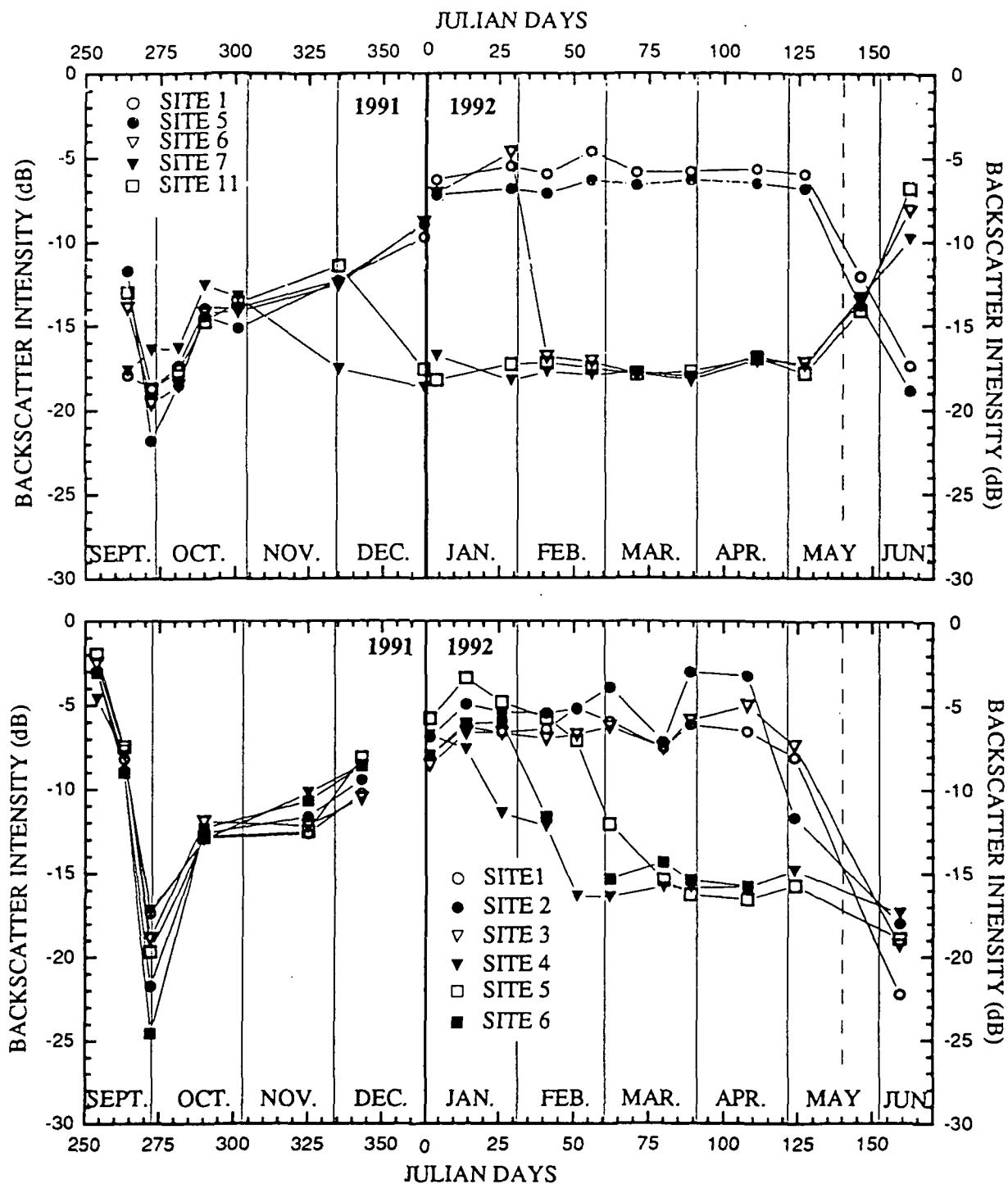


Figure 1. Backscatter intensity as a function of time during winter 1991-92 from coastal lakes close to Barrow (top) and inland lakes (bottom) approximately 80km south of Barrow, Alaska. The broken vertical line in May identifies the onset of mean daily temperatures >0°C at Barrow.

DISCUSSION

At the time of initial ice growth, the weak backscatter is probably due to specular reflection off the smooth upper and lower surfaces of the thin ice and thus relatively little signal return to the radar. The decline in backscatter from different lakes at different times during the winter can be attributed to the ice freezing to the bottom of lakes with different depths. Absorption of the signal in the soil accounts for the low backscatter intensity once the ice grounds.

At all sites where the ice was frozen to the bottom in April, there were tubular bubbles in the ice. This suggests that the tubular bubbles must act largely as forward scatterers as the radar signal passes through to the base of the ice. Since there is a minimal return to the radar once the ice is frozen to the bottom, the strong backscatter that is observed in the ice prior to grounding and in the ice that remains afloat all winter must require the presence of both an ice-water interface and the tubular bubbles.

An ice-water interface has a strong dielectric contrast that will give rise to specular reflection. However, at the time the lakes were sampled, there was strong backscatter at those sites where the ice was still floating. The only explanation for the strong backscatter is the presence of the tubular bubbles, which scatter the signal both before and after it is specularly reflected off the ice-water interface.

The backscatter reversal observed in the coastal lakes at Barrow has not previously been reported. It occurred during the spring thaw period (Fig. 1). Why grounded ice and floating ice with previously low and high backscatter intensity, respectively, should subsequently give cause high and low backscatter intensity during the thaw season is unclear. At the same time, backscatter declined at all the inland lakes. This is what might be expected in spring when factors such as a melting snowcover will attenuate the radar signal and reduce backscatter.

CONCLUSION

There are considerable backscatter intensity variations from ice growing and decaying on shallow tundra lakes. From the time of initial ice growth until shortly before the thaw period, time-series of backscatter variations from these lakes are a record of: 1) initial ice growth and subsequent thickening; 2) the development of tubular bubbles in the ice and, by association, gas saturation of the underlying water; and 3) the freezing of ice to the bottoms of the lakes and, therefore, lake bathymetry and water availability. During the thaw period, there are unusual patterns of backscatter intensity that remain to be explained before SAR can be used effectively to identify the timing of break-up and to understand break-up processes on these shallow tundra lakes.

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